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ABSTRACT

This paper presents the features of graphic calculator technology that can be implemented in noncalculus-based educational statistics courses. The objectives are to: (1) present potential uses of the graphing calculator; (2) discuss current research concerning graphing calculator implementation in the classroom; and (3) illustrate current instructional strategies advocated for use in the statistics curriculum. On-going studies have indicated increases in conceptual understanding through the use of graphing calculators. While computers may not always be available to students, the hand-held calculator can be used in the classroom and at home. Screens with data, output, and programs are illustrated. With the opportunity to see available technology used with real data and activity-based learning, teachers of educational statistics can lay a better foundation for their students. An appendix presents simulation programs for the Sharp EL-9300 calculator. (Contains 22 references.) (Author/SLD)

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USING GRAPHING CALCULATOR TECHNOLOGY IN EDUCATIONAL STATISTICS COURSES

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ABSTRACT

This paper presents the features of graphing calculator technology that can be implemented in non-calculus-based educational statistics courses. The objectives of this paper are: 1) to present potential uses of the graphing calculator to the audience, 2) to discuss current research concerning graphing calculator implementation in the classroom, and 3) illustrate current instructional strategies advocated for use in the statistics curriculum. While computers may not always be available to students, the hand-held calculator can be used in the classroom and at home. Screens with data, output and programs are included in the paper. With the opportunity to see available technology used with real data and activity-based learning, teachers of educational statistics can lay a better foundation for their students.

USING GRAPHING CALCULATOR TECHNOLOGY IN EDUCATIONAL STATISTICS COURSES

In recent years, the advent of graphing calculator technology has influenced the teaching of mathematics and statistics in a profound way (Dunham & Dick, 1994; Demana & Waits, 1989; Fey & Good, 1985). This paper will exhibit some of the features of this technology that can be implemented in non-calculus-based educational statistics courses. Screens with data and output and programs are included in the paper. Calculators are available for the audience to explore after the discussion session. Graphing calculators enhance computer software in statistics rather than replace it. While computers may not always be readily available to students, the hand-held calculator can be used in the classroom or at home. This feature alone makes the graphing calculator a powerful tool in a statistics course.

Leitzel (1993) urged college faculty to implement graphing calculator technology into their curricula since the majority of high school graduates have a working knowledge of graphing calculators. With so much success at the high school level (Osborne et al., 1989) many colleges have begun to implement the use of graphing calculators in their mathematics departments. Teachers of educational statistics are now dealing with a large student population that are carrying this hand-held technology with them to class and wishes to continue its use. Students' understandings of concepts via the use of a calculator will have benefited them in previous courses. Graphing calculators can be used to teach concepts and methods and de-emphasize number crunching (Gilchrist, 1986).

In order to take the Advanced Placement Calculus Test, the College Board now requires each student to have a graphing calculator (Gleick, 1995). The Texas Education Agency furnishes graphing calculators to college students when they take a mathematics/statistics certification exam.

The objectives of this paper are: 1) to present the potential uses of the graphing calculator to the audience, 2) to discuss current research concerning graphing calculator implementation in the classroom, and 3) illustrate current instructional strategies advocated for use in the statistics curriculum.

POTENTIAL USES FOR GRAPHING CALCULATORS

The potential uses of the graphing calculator are presented by looking at topics such as, but not limited to, the following areas. One variable descriptive statistics will be covered first followed by an in-depth coverage of two variable statistics. Regression, residuals, and correlation are analyzed through a variety of representations on the calculator. Many types of graphical representations of one and two variable statistics are explored due to the vast capabilities of the graphing calculator. Programs written for the calculator are included in the paper and illustrated. Programs such as probability simulations and regression analysis are just two examples

Summarizing Data -- Numerical One Variable

The Survey of Study Habits and Attitudes (SSHA) is a psychological test that evaluates the motivation, study habits, and attitude toward school of college students. A selective private college gives the SSHA to a sample of 18 of its incoming freshman women. Their scores are:

154 109 137 115 152 140 154 178 101

103 126 126 137 165 165 129 200 148

The measures of central tendency and dispersion using the graphing calculator are:

$\bar{x}$ = 141.0555556
sx = 26.43632132
σx = 25.69148632
Σx = 2539.
Σx^2 = 370021.
n = 18.
xmi = 101.
xmq = 200.

Sort the data using the graphing calculator.

Find:

Median = 138.5; Q1 = 126; Q3 = 154; IQR = 28; 1.5 X IQR = 42

Outliers can be determined by subtracting 1.5 X IQR from Q1 or by adding 1.5 X IQR to Q3 and seeing if any of the scores lies outside these quantities.

126 - 42 = 84 and 154 + 42 = 196

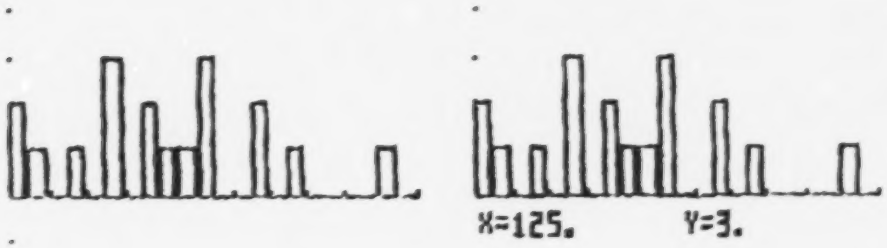
There is one outlier since the score 200 is above 196.

Summarizing Data -- Graphical One Variable

The same data can be used to look at statistical graphs.

A box plot can be graphed by hand using the statistics above.

There are seven types statistical graphs available on the Sharp 9300. They are the histogram, broken line, cumulative frequency, normal distribution, scatter diagram, regression curves, and two variable box chart. The types of regression curves are linear, exponential, natural log, log, power, and inverse. Since the following data is one variable the screen for the histogram is shown below. The second graph screen has the trace option activated.



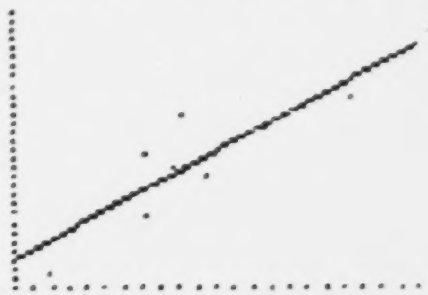
You can recognize clusters, gaps, and possible outliers by looking at the histogram.

Summarizing Data -- Graphical and Numerical Two Variable

The mathematics department of a large state university must plan in advance the number of sections and instructors required for elementary courses. The department hopes that the number of students in these courses can be predicted from the number of entering freshmen, which is known before the new students actually choose courses. The table below contains the data for recent years (Moore & McCabe, 1989). The explanatory variable x is the number of students in the freshman class, and the response variable y is the number of students who enroll in mathematics courses at the 100 level.

Year	1980	1981	1982	1983	1984	1985	1986	1987
x	4595	4827	4427	4258	3995	4330	4265	4351
y	7364	7547	7099	6894	6572	7156	7232	7450

The screen below is the scatter diagram and the linear regression graph.



The linear regression equation and correlation coefficient are given below.

```
Regression
[1:a+bX]
a   = 2492.691752
b   = 1.066322358
r   = 0.833258238
```

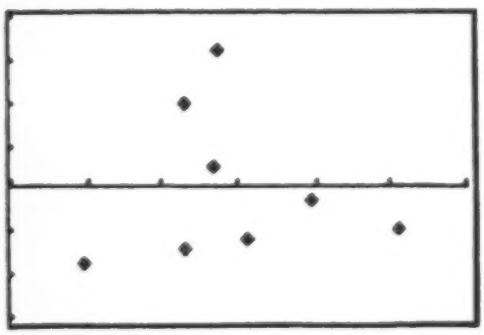
The TI-82 calculator allows data to be entered in list format. Using the mathematics department data, List 1 represents the x-values and List 2 represents the

y-values.

We can further analyze this data by looking at the residuals. Residuals are the vertical distances between the data points and the predicted values that lie on the regression line. Examining these residual values makes it possible to see the appropriateness of the regression line. List 3 evaluates the regression line at every value of x from List 1. List 4 then shows the difference in the actual data points and the predicted values, the residuals.

L1	L2	L3	L4	L5
4595.0	7364.0	[illegible]	-114.3	1982.0
4827.0	7547.0	7639.8	-139.1	1983.0
4427.0	7099.0	7213.3	-180.6	1984.0
4258.0	6894.0	7033.1	46.132	1985.0
3995.0	6572.0	6752.6	191.44	1986.0
4330.0	7156.0	7109.9	317.74	1987.0
4265.0	7232.0	7040.6	------	[illegible]
L3(1)=7392.4429...				

Not only can we calculate the residuals and examine them numerically, we can graph them to show the positive and negative aspects.



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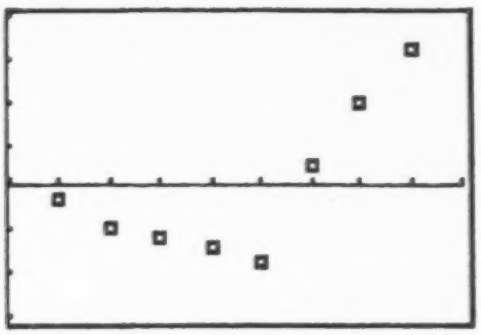
Finally, it is possible to graph the residuals over time. By putting the years in List 5 and plotting the residuals (List 4) versus time (List 5), we can get the following plot.



Programs

Many programs can be written for graphing calculators. The COINTOSS program uses the random number generator to simulate the toss of a fair coin N times. The DIERACE and COINRACE programs explore random numbers, binomial and uniform distributions, histogram construction, simulations and the Central Limit Theorem. The LSLINE program allows for exploration of linear regression by having students try to minimize the sum of squares of the deviations. These programs are included in Appendix A.

Exponential Decay

Infant mortality is an important measure of quality and availability of health care. We measure infant mortality by the number of children who die within the first year of life out of 1000 who are born alive. Infant mortality in the United States has declined as follows:

1920	1930	1940	1950	1960	1970	1980
85.8	64.6	47.0	29.2	26.0	20.0	12.6

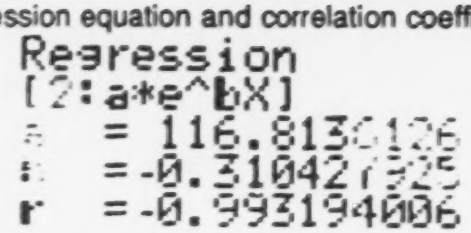
The scatter diagram follows:

The linear regression graph and the exponential regression graph follow:

The linear regression equation and correlation coefficient are:

```
Regression
[1:a+bX]
a   = 87.85714286
b   =-11.77857143
r   =-0.960420961
```

The exponential regression equation and correlation coefficient are:



REVIEW OF CURRENT RESEARCH

Since the introduction of graphing calculators, there have been numerous articles dealing with how to incorporate them into the classroom or their appropriate use for a particular subject. What has been lacking is significant research to show the effectiveness of the calculators or how using them affects students and teachers. This has only recently begun to change. What follows is a summary of reported findings dealing with graphing calculator research.

The main area of research seems to be on the calculators in general. Findings that the calculators make calculations less tedious (Harvey, Waits, & Demana, 1995; Quesada, 1994) and allows the use of real data (Dunham & Dick, 1994) are common. A less common area of reporting deals with test scores and performance. However, there are studies that show student improvement with the use of the calculator (Carlson, 1996; Harvey, Waits, & Demana, 1995; Quesada, 1994). Finally, results dealing with teacher and student attitudes toward the technology will be reported (Berver, 1996; Carlson, 1996; Kepner, 1994).

According to Harvey, et al. (1995) not only were the tedious calculations no longer of concern to students who used a graphing calculator, but the machine facilitated focusing on algebraic concepts and problem solving and less on

procedures. These same results were echoed by Quesada (1994). Along those same lines, McClendon (1992) reported improved problem solving skills among students using the calculator.

Due to the nature of a graphing calculator, several studies have focused on students' understanding of graphical material. Beckmann (1989) showed that students are able to obtain more information from a graph after experience using the calculator. The ability to better read and interpret graphical data (Boers-van Oosterun, 1990) is another positive result of use of the calculator. Harvey, et al (1995) not only reported similar findings, but went on to say that multiple graphical representations were more easily understood by the students in the group.

The above mentioned results were all positive outcomes of students who used a graphing calculator, but only Harvey goes on to report performance results. According to the study, there was a significant difference on pre and post tests between the experimental and control groups in the study (Harvey, Demana, & Waits, 1995). Quesada (1994) also found a significant difference with precalculus and calculus students. At the University of Kansas, the pass rate of college algebra students is up from 50% to 72% since to introduction of graphing calculators into the curriculum (Carlson, 1996). The same study reported that students felt more content and were more interested that any other group of students in the past ten years.

A less scientific, but just as important aspect of graphing calculator research deals with the attitudes of students and teachers who are working the

calculators. Berver (1996) found that 89% of student responses required to purchase a graphing calculator were positive. The study also showed a direct relationship between teacher attitudes toward the machines and their students attitudes. These results could explain the tie between University of Kansas teachers who felt the calculators had a positive impact on class interest and understanding and University of Kansas students who reported their understanding and interest had been positively affected by calculator use (Carlson, 1996). Kepner (1994) dealt solely with teacher attitudes. Teachers involved in a three year program did have major changes in their beliefs, skills and implementation, but these results came after the three year period.

The published data regarding graphing calculator research studies is not abundant. Because of this, two ongoing studies are being done by the authors of this paper. In one study, funded by the Montclair State University Faculty Scholarship Incentive Program, results have shown that teachers who participate in a one-week summer workshop on graphing calculator training have a significant increase in conceptual understanding ($p<.001$) as measured by a pre and post test. The other study is a joint venture between The University of Texas at San Antonio and Montclair State University. This joint venture involved the development and implementation of a mathematics course designed for preservice mathematics teachers where graphing calculator technology usage and applications were modeled. The results of this joint venture also indicated significant increase in conceptual understanding ($p<0.0001$) as measured by a pre and post test.

There is little doubt as to the benefit of graphing calculator technology in the classroom. Compared to computers, the advantages of portability, affordability and user friendliness cannot be argued (Cheung, 1996). The stumbling block remains conversion of teachers to use the technology and schools to purchase the necessary equipment. It seems from the research students do not need to be convinced.

STATISTICS INSTRUCTIONAL STRATEGIES

Statistics courses have become one of the essential courses included in the undergraduate and graduate college curriculum and the number of statistics courses offered at the university level is increasing every year. (Gordon & Gordon, 1992). Some of the suggested improvements for statistics courses are implementing real-world data sets, projects, cooperative learning, and automated computation. Singer and Willett (1990) wrote that in order to improve statistics courses education, artificial data sets should be eliminated from the curriculum and replaced with real data sets. Real data sets are: authentic; interesting and relevant; have background information available; and multiple analyses can be performed on them. They also provide substantive learning and can be presented in raw form.

David Moore (1992, p. 20-23) discussed principles for improving statistics education by emphasizing data and concepts at the expense of theory and to "automate calculation and graphics as much as possible." Allen, Efird, and Eliasziq (1990) reported that introductory statistics students need to learn how

to interpret results, formulate questions from a data set, solve real-world problems, and learn formal writing skills. Hogg (1992) suggested that to improve statistics education goals should be stated, data should be analyzed, computation should be automated, projects should be implemented, and lectures should be de-emphasized. The importance of technology in statistics education is an issue discussed in *Statistics for the Twenty-First Century* (Gordon & Gordon, 1992). Also considered in the development of this paper is the opportunity to demonstrate how real-world data can be used in the statistics classroom. Too often "canned data" is used with students and they do not develop a real sense of the uses of statistics (Scheaffer, 1990; Singer & Willett, 1990). Recent studies show that activity-based learning in the area of statistics is desired in order for deeper understanding of the concepts (Mittag, 1993; Taylor, 1993).

CONCLUSION

Statistical knowledge is of paramount importance in society today. Exploratory data analysis, real-world data sets, computers, and calculators will all be extensively utilized in the future statistics classroom. With the opportunity to see available technology used with real data and activity-based learning, teachers of educational statistics can lay a better foundation for their students. This paper and presentation allowed the authors to explore the available technology, present current research, and discuss the impact of graphing calculator technology on the educational statistics curriculum, instructor, and classroom.

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APPENDIX A

PROGRAMS FOR GRAPHING CALCULATORS

SIMULATION PROGRAMS FOR THE SHARP EL-9300

Program COINTOSS uses the calculator's pseudo-random random number generator to simulate the toss of a fair coin N times. To execute the program, press [⇧] A followed by the number next to the name "cointoss". When prompted, enter the value of N and watch the results of the coin flips. What values should the relative frequency of tails (represented by the rectangles on the left of the screen) and the relative frequency of heads (represented by the rectangles on the right of the screen) approach as the value of N increases?

Program cointoss (STAT)

```
ClrG
Stat X
Input N
H = .8N
Range 0, 1, 1, -.5, H, 1, 2
t = 1
Label 1
R = ipart 2 random
Data R
G(HIST)
t = t + 1
If t <= N Goto 1
End
```

The following two programs, the Histogram Horse Races, allow the student to explore and gain a better understanding of random numbers, the binomial and uniform distributions, histogram construction, coin toss and die roll simulations and the Central Limit Theorem.

Program dierace (STAT)

```
ClrG
Stat X
Input N
H = .3N
Range 1, 6, 1, 0, H, 5, 6
t = 1
Label 1
R = ipart 6 random + 1
Data R
G(HIST)
t = t + 1
If t <= N Goto 1
End
```

Program coinrace (STAT)

```
ClrG
Stat X
Input N
H = .3125N + 5
Range 0, 5, 1, 0, H, 5, 6
t = 1
Label 1
R = ipart 2 random + ipart 2 random +
    ipart 2 random + ipart 2 random +
    ipart 2 random
Data R
G(HIST)
t = t + 1
If t <= N Goto 1
End
```

The program that follows, Isline, allows the student to explore linear regression by trying to minimize the sum of squares of the deviations (SSD). N points are randomly generated and

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stored in the statistics data cards, the scatter diagram is drawn, and the user is asked to input guesses for the y-intercept and slope of the best fitting line. N should be greater than or equal to 4 for effective use of the program. When it is felt that a value of SSD close to the minimum value is found, the user of the program should choose the "do not try again option" by entering a value for t other than 1. The program will then draw the least squares regression line on the graph for comparison with the user's last attempt. The regression coefficients are then displayed along with the minimum sum of squares of the deviations and the correlation coefficient. Whenever the program pauses, the user should press [ENTER] to resume execution.

Program lsline (STAT)

```
ClrG
Stat XY
C = 1
Input N
Label gen
M = ipart 9 random – 4
W = ipart 7 random – 3
If M = 0 Goto gen
If W = 0 Goto gen
Data M,W
C = C + 1
If C < N Goto gen
Data x̄ , ȳ
Range -4.7, 4.7, 1, -3.1, 3.1, 1, 1
G(S.D.)
Wait
ClrT
Print " Line is y = A + Bx "
Label guess
Print " Enter guess for y intercept "
Input A
Print " Enter guess for slope "
Input B
X = -4.7
F = A + BX
X = 4.7
G = A + BX
Line -4.7, F, 4.7, G
Gosub residual
Gosub prt
Print " To try again, enter 1 for t "
Input t
If t = 1 Goto ls
DispG
Wait
ClrG
If t = 1 Goto guess
Label ls
G(line)
Wait
Print " Least squares line y intercept "
A = a
Print A
Print " Least squares line slope "
B = b
Print B
Wait
ClrG
Gosub residual
G(line)
Wait
Gosub prt
r = r
Print r
Wait
DispG
End
Label residual
k = 1
s = 0
Label calc
x = St[1,k]
y = St[2,k]
Y = A + B*x
s = s + (y – Y)²
Line x, y, x, Y
k = k+1
If k <= N Goto calc
Wait
Return
Label prt
Print " SSD = "
Print s
Wait
Return
```

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